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Agricultural and Food Chemistry: The Road Ahead

"He that will not apply new remedies must expect new ills for time is the greatest innovator."
—Francis Bacon (circa 1630)

This year we celebrate the 80th anniversary of the founding of the Agricultural and Food Chemistry Division of the American Chemical Society (ACS). With any such milestone of longevity for an organization there comes a time for reflecting upon the character of that organization, the "stuff" that has enabled us to grow, endure, and thrive. We look over our shoulder to where the Agricultural and Food Chemistry Division has been and how it reached where it is today and, most importantly, we turn to what might lie ahead.

LOOKING BACK

Since the future is in large measure a continuation and evolution from our past, to look ahead we must look back! Five years ago at the time of our Diamond Jubilee, we published the Division's history, tracking its growth and success from humble beginnings in 1908 as one of the first five ACS Divisions (Zikakis, 1983). Earlier this year we further expanded upon that look back, tracing out the litany of collective and individual accomplishments whose sum total made our Division what it is today (Prebluda and Brine, 1988). In retrospect, from the history of the first 80 years one readily can conclude that the Agricultural and Food Chemistry Division has been a great communicator of new scientific ideas and an innovative leader in establishing new technological trends.

Over 100 years ago, prior to the founding of the ACS, agriculture was much more an art than a science. Common sense and tradition were woven into the fabric of the "trial and error" research of that era. Justus von Liebig, the "father of agricultural chemistry", and his European colleagues were the pioneers in applying the scientific method to the identification of food constituents as proteins, carbohydrates, fats, and minerals. Early leading U.S. agricultural and food scientists (e.g., Samuel W. Johnson) trained under the Liebig system. They and their protégés spearheaded the establishment and development of the agricultural experiment stations and affiliated colleges system so essential to the phenomenal success of U.S. agriculture and agricultural research during this century. Many of these same scientists played a key role in the founding of the ACS and later the Agricultural and Food Chemistry Division. Agricultural science was focused on soil and fertilizer chemistry as means of improving crop quality and yields. An exciting era in food chemistry was just dawning, and a century of remarkable research achievement was ahead in the United States.

The early days of the Agricultural and Food Chemistry Division, the era of Professors Wheeler, McCollum, and others, were challenging times for the chemists and scientists engaged in research. With the full implementation of the Hatch Act (1889), and through the founding of the Agricultural Extension Service (1914), substantial federal funding provided an impetus for research through the system of state agricultural experiment stations and universities. Agricultural research became popular and was in full bloom. Unmistakably, we furthered the collective knowledge of plant, animal, and human nutrition and the food and agricultural systems contributing to them. The funding, provided willingly by the federal government through its agencies, benefited society greatly in the years to come. Although the near-term applications of the results of such research were numerous and noteworthy, the long-term view of the ultimate value of augmenting our scientific knowledge base was widely held by those in positions of authority.

In the early part of this century the U.S. agricultural and food scientists pioneered in many new areas of research, setting the technological trends in agricultural production methods, agronomy, plant science, disease control for animals, and plant and animal nutrition. They were leading the drive for innovation long before the public or many in government understood the practical benefits of their research or were educated sufficiently to grasp its long-term implications. For example, Professor Elmer V. McCollum, an early member of our Division, led the charge in the basic concepts of nutrition (Prebluda, 1984). His landmark findings with then unknown growth factors, now known to us as vitamins, most certainly had immediate application to the alleviation of rickets, the animal and human vitamin D deficiency condition. The full harvest of vitamin research initiated almost 80 years ago by McCollum is still being reaped today in the production of almost 6 billion U.S. broiler chickens per year, an impossibility without vitamin D products. McCollum did more than any man to put natural foods such as milk, fresh fruit,

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and salad greens into the American daily diet. Our balanced, vitamin-fortified diet of today has helped lengthen our life span and dramatically improved the nutritional health of the U.S. population.

Similar success stories can be recounted about dozens of highly talented agriscientists whose research has benefited society for decades and will continue to do so long into the future. Largely as a result of their research efforts, today less than 3% of the total U.S. labor force is required to provide the basic food and fiber for this nation and world export, whereas last century greater than 50% was necessary. The total U.S. corn harvest today is nearly 7 times as great as it was a century ago, and its nutritional value is highly improved. Meat and egg production has more than doubled in the last 50 years whereas soybean production has nearly tripled. Chickens today can be grown to maturity on half the feed in half the time compared to 35 years ago. Animal vaccines developed in the last 50 years are estimated to save annually several billion dollars worldwide.

Key to their success over those years was the unwavering level of food science and agricultural research funding offered by the USDA under the Hatch Act and associated programs. In fact, during the lifetime of our Division more agricultural and food research has been carried out under U.S. government and industry sponsorship than by any other nation in the world. However, in the last decade the trend in funding has been decreasing. Government funding of food science and agricultural research recently has lagged behind our principal rivals for technical leadership (England, France, Germany, Japan). Industrial research funding has stagnated at a level of 0.75% of food sales. Continuance of this trend in the long run will undermine the research base that has made the U.S. the competitive world leader in agriculture.

The reasons for this decreased funding trend are varied and reflect basic changes in U.S. societal priorities in these last decades. In one sense, U.S. agriculture has been a victim of its own great success as repeated bountiful harvests ultimately became huge farm surplus problems. The public and the policy makers' collective awareness and attention turned away from the basic priority of improved food production as a cavalier attitude of "always plenty" developed over the last decades. The collective memory of times of need, such as the U.S. dust bowl days of the 1930s, grew short and hazy. Longer term research thinking gave way to a quick-return, bottom-line orientation in industry and government. The elected legislators and government agency leaders began to reflect the public's "so what" attitude toward ongoing scientific advances and innovative achievements. This loss of public capacity for wonder, fostered by the overexposure of science by the mass electronic media and dramatically typified by the public attitudes that developed toward our space program, resulted in an overall loss of respect for the value of the science. The chemical industry and, by implication, to some extent all chemical research came to be perceived wrongly as a serious threat to the environment. Then too, agriculture and agriscience became too closely associated in the public mind with big agribusiness, leaving them as prime cutback targets as economic times and budgetary constraints tightened. In short, as in the industrial sector, we as a nation had grown complacent with success and began to lose sight of the drive for research and innovation that had made us great.

As we look back over the past 80 years of the Agricultural and Food Chemistry Division and turn toward the present, the legacy includes a record of glorious, lasting achievements that have improved our quality of life immeasurably. It also includes the recent decades of declining public enthusiasm and support for the chemical sciences, in general, including agricultural and food chemistry. Hence, a major goal and challenge today facing our Division, and the ACS in a larger sense, is the education of the public and the enlightenment of our governmental leaders to continue a strong program of agricultural research to provide a bright economic future for the nation.

THE PRESENT

The present, representing the transition between our past and our future, is a time of significant change in agricultural and food chemistry. It is no secret that during the last two decades, despite significant innovation and improvement in efficiencies, farming and agricultural production have been in a serious state of economic stress. Huge farm surpluses have plagued economic recovery as world demand for U.S. agricultural products continued to decline. During that same time, however, the application of food chemistry and technology to the production of prepared foods in the United States has blossomed and really arrived in most definitive terms. Today it is where most all the industrial research funding is concentrated. A substantial share of the present government funding is earmarked for this purpose as well.

In recent years the American public has come to expect immediate application to research findings and innovations, especially in the foods area. This has brought ease and comfort to our lives and helped us cope with the constantly changing modern lifestyle. The economic and political will of the consumer, translated into research funding, now drives the applied food chemical research. Market forces and consumer preference trends point the direction for the applied innovator and indicate where the focus of the research will be heading in the short term.

One trend that is unmistakenly clear from the modern, two-income family lifestyle is that America has become a nation of convenience food "hunters", demanding evermore instantly prepared foods. In 1950, about 1000 food items could be found in the typical food store, with many of the staple variety. Presently in the typical supermarket one can see over 15 000 food items, the vast majority with convenience or instant preparation built into them. As a nation we spend 14% of our earned income on such prepared foods. Today, the microwave oven is king. Current estimates are that 7 out of 10 U.S. households have and regularly use microwave cooking to prepare foods. Indications are this percentage will rise still higher in the decade ahead. In fact, this trend has set in with such persistent vigor that this year a major processed foods company has committed over 30% of its multi-hundred million dollar R&D budget to making its products microwaveable. They are not alone. Recent food trade shows have been featuring new entries into this market, and the mass media is flooded with advertisements extolling the virtues of a spectrum of microwave-prepared foods. Everywhere applied food chemistry laboratories are engaged in research aimed at the improvement of the preparation, processing, and packaging of foods for microwave use.

Along with this drive for convenience foods that fit the modern lifestyle comes the need for new preparative and packing technology, new methods of testing to assure quality, and new means of introducing and preserving flavors for freshness in prepared foods. For along with their desire for convenience, consumers have shown that they value natural and fresh-tasting foods and desire their availability year round. They have shown as well an increasing awareness of and preoccupation with the implications of long-term diet, nutrition, and health. Recognizing this aspect of the convenience food trend as an ongoing concern, the Agricultural and Food Chemistry Division formed a subdivision of Food Safety in 1987 to address critical issues on natural toxins, additives, microbial toxins, chemical changes during food processing, and other antinutrients found in prepared foods.

Today, as a product of the convenience food industry, research has been accentuated in broad areas covering food flavors, antioxidants, preservatives, and food chemistry as related to new prepared foods and packaging. It is likely to increase even more over the next decade. Food flavors that remain natural, palatable, and freshly delicious during both processing and instant preparation have become essential. The development of natural flavors using fermentation techniques, already under way, is likely to increase in the decade ahead. Research is in full gear on antioxidants to preserve fatty acid derived flavors and avoid the degradative effects that can occur during processing, packaging, storage, and use of modern prepared foods. Innovation with picowaving, the use of low-level radiation to preserve specially packaged foods for long shelf life without refrigeration, has begun in earnest. Aseptic packaging for beverages, a relatively new phenomenon, has swept the U.S. juice-canning industry by storm. In 1987, in the mature U.S. canning industry, aseptic packaging was the one bright spot, showing a 6% advance with no signs of a slow down in future growth. Millions of dollars of R&D money has been and is being invested in designing and developing food-packaging systems oriented to the needs of microwaving. In all these areas, applied research in food chemistry is running at a brisk pace in an attempt to stay at least a half-step ahead of consumer demand.

Another leading, consumer-driven trend providing a major stimulus for research and development today is in the area of human nutrition and diet. As more about the role of diet, long-term nutrition, and human health has become known, the American public has come to demand greater information on the nutritional safety and efficacy of the food supply they consume. Although fraught with misconceptions and subject to mass media induced wrong perceptions, the public awareness and consciousness of this issue has been raised. The public demands to know all that the food and nutritional chemist can tell them regarding the food they eat and its effect on their health. A large part of the overall job of today's food and nutritional chemists is to aid in separating nutritional fact from fiction and in eliminating sources of distorted public perception. By focusing scientific truth into an area littered by false, opportunistic claims, we can continue to do a great public service.

Owing to both valid public concerns about overweight-induced health problems and public perceptions about "eating oneself thin", alternative lower calorie sweeteners have been and are the source of ongoing, highly funded research and development efforts in the United States. Several such sweeteners are on the market, and more are in various stages of testing for FDA approval. It is a safe bet this trend will continue into the next decade. The dietary role of cholesterol, implicated in 85% of the 550000 annual U.S. deaths from coronary disease, has gained a huge amount of attention in the last 10 years. Estimates are that the potential markets for drugs in development to combat the effects of cholesterol are in the billions of dollars. Consequently, great emphasis is now being placed on developing acceptable dietary fat substitutes low in saturated fat fractions. Efforts to breed cattle to produce leaner beef and lower fat/lower calorie dairy products have greatly increased in recent years as the per capita consumption of these traditional products has declined. In fact, in 1987 for the first time U.S. poultry per capita consumption (80 lb) exceeded beef consumption (75 lb) with predictions that by 1990 it could augment its lead to 25% or more. At the same time, public concern about cholesterol and excess calories in the diet led to a 5% gain in 1987 U.S. per capita seafood consumption and a 5-year gain (1982–1987) of over 25%. The role of dietary fiber both in promoting good digestive health and in reducing dietary cholesterol had led to large increases in basic and applied research on this subject. U.S. sales and consumption of high-fiber cereals and baked goods, perceived to be higher in fiber, have escalated. All of these trends can be expected to continue and become even more pronounced in the decade ahead as more information linking diet and health becomes available to the consuming public.

Another driving force in shaping the direction of today's research revolves around persistent public concerns for the environment. It is obvious to us all that we must turn our attention increasingly toward dealing with the effluents and waste products of our modern, industrial society if we are to maintain reasonable quality of human life as world population increases. Along these lines, considerable work to convert waste products to useful materials and to utilize biorenewable resources, stimulated in the 1970s during the energy crunch, continues today. For example, USDA-sponsored research has demonstrated recently the possibility of chemically polymerizing surplus corn starch into biodegradable plastics for potential use as food wraps, containers, and the like. Other USDA-sponsored research is being directed at converting our agricultural waste products, such as wheat straw, corn stover, sugar beet pulp, etc., into useful animal feeds. Recent research has shown, as well, that lactic acid, available in large volumes by fermentation of corn or sorghum, can be polymerized into environmentally benign plastics to replace nondegradable PVC, polystyrene, and commodity acrylics in a host of traditional applications. The natural polymer chitin, derived from seafood processing shell waste, is today being utilized commercially in surgical sutures and burn dressings (Austin et al., 1981). Chitosan (deacetylated chitin) is finding uses in lowering dietary cholesterol, metal chelation, wound treatment, and waste water flocculation. In a novel application, chitin has been shown to be useful as an animal feed supplement to promote lactose digestion and thereby potentially allow surplus cheese whey to be utilized as animal feed (Austin et al., 1981).

Thus, the present is a time of change for agricultural and food chemistry. Rapid application of research findings, particularly in the area of food chemistry and technology of prepared foods, is the order of the day, with the U.S. public setting the tone through their collective trends in consumption. Market forces, in large part, have become a major factor in driving innovation and the scientist finds himself just as often following as well as leading the technological trend. But, as surely as this change has come to pass during this century, the road into the future promises change once again. The challenges in food production we as a society will face in the next century are at once imposing and awesome. We will need to bring to bear once again the best that our scientific minds can offer to meet these future challenges.

LOOKING AHEAD

As we look toward our future, we see the world of the next century being more populated, still threatened by environmental pollution, with obvious shortages of energy, chemical feedstocks, and water. Also, the world will be more complex socially, economically, and politically. It will be a world of greater challenges and problems but also one with great opportunities for those engaged in agricultural and food research. To address the great needs for new sources of food, fuel, and raw materials, our scientists will be called upon for new answers and technical innovations. To be ready with those answers, it is imperative that the required research be under way today.

Having recognized that the future scientific advances, the answers to tomorrow's pressing urgencies, are in the laboratories of today, the Division of Agricultural and Food Chemistry can point with pride to the leadership we have taken in biotechnology. In 1985, we organized the first ACS interdivisional Secretariat on Biotechnology (Phillips et al., 1988). It was with a realization of the complexity of global issues of the future and the key role biotechnology and genetic engineering will play in their successful confrontation that the Division vigorously fostered this interdisciplinary approach by the ACS.

By the turn of the 21st century, our knowledge and application of genetic engineering will have increased many-fold. Recombinant DNA technology will have become a most powerful tool to improve agricultural technology and address critical problems in food, energy, and bioresources. U.S. agriculture and the related sciences will be revolutionized in a manner and time frame unforeseen just a few years ago. The fruits of biotechnology, based on our scientists' ability to converse in nature's own language, the genetic code, will provide a significantly more efficient system of food and biofeedstock production and one that is far more environmentally compatible. Engineered crop plants will have greater disease and pest resistance, the ability to better endure climatic stress, and the propensity for self-growth regulation to maximize outputs/minimize required inputs (e.g., fertilizers). Livestock will be genetically improved for more efficient and leaner meat production. Food crops will be made more nutritious, and genetic engineering of nitrogen-fixing organisms may enable the efficient fixation of nitrogen in the soil for nonlegume crops and even nontraditional crop plants (e.g., marine salt-tolerant halophytes). This could allow considerably more economic production of starches, sugars, and vegetable proteins and lessen our continued dependence on fertilizers, which require a great deal of energy and cause many environmental problems.

Improved bioengineered enzymes and microorganisms also will play a greater role in the development of better food, food processing, and bioresource products. This may lead the way to significantly greater applications of advanced immobilized enzyme technology in continuous reactors for specific reactions and conversions in the chemical and food industries. We already see examples of the beginnings of this trend in the recently FDA-approved use of specific lipase enzyme systems to convert palm kernel oil to cocoa butter analogues for use in chocolate products, the introduction of the first lipase detergent enzyme, and an improved renin for cheese making. All were made via genetically engineered microorganisms. By the end of this century, genetically manipulated microbial, fungal, and whole-cell cultures may be utilized to manufacture a wide range of highly beneficial biotechnical and organic chemicals that today cannot be produced economically. The chemical process industry could be transformed into the biochemical process industry.

Biopesticides, already allowed by the EPA, will become more the rule than the exception as we seek to increase crop yields in an environmentally friendly manner. In the 21st century, biotechnologically produced vaccines, several even now in various stages of development and testing, could revolutionize efficiencies in animal production many times more than their standardly produced predecessors did during this century. Major advances in plant and animal growth regulation should allow the development of highly productive species of each.

Energy will again become a serious concern as we whittle away at our traditional fossil fuel reserves. Improved fermentation and bioconversion schemes with known chemurgic, renewable resources such as starch, lignin, cellulose, hemicellulose, and chitin will be turned to initially to buy some transition time. Ultimately, however, the bioengineering of green plants could render them capable of direct oil production to satisfy our fuel needs and greatly improve our ability to convert biomass to chemical feedstocks to supply our industries. Substantial reductions in our energy requirements might result from the lessening of synthetic fertilizer needs as genetically engineered, nontraditional nitrogen fixers are cultivated in the same way as grains and legumes are today. Biotechnical advances with marine plants and organisms may open up wholly new, biorenewable sources of fuel and feedstocks (e.g., algae), which could be cultured and "farmed" such as terrestrial crops traditionally have been.

Perhaps to a greater extent than energy, water will become a paramount 21st century issue. Water is the lifeblood of agriculture, and there are no bioalternatives to replace it! According to the most recent USGS water report for 1985, farming now accounts for 42% of all U.S. water usage, and in the perennially dry Western states, 85% of the water used goes for crop irrigation. The present U.S. drought situation has heightened our awareness in a dramatic way of the time bomb potential the "greenhouse effect" could have on our climate and our agriculture. Biotechnology could become a means of counteracting the devastating effects of repeated, widespread drought conditions in our prime farming areas. Barring a massive and unforeseen reduction in the burning of fossil fuels worldwide, one possible ongoing effect on U.S. agriculture could be the need for long-term, large-scale migration of staple crops to now marginally arable growing areas. Coastal areas and salt marshs are less likely to be impacted by climatically induced water shortages. They may become principal growing areas where salt-tolerant, genetically engineered halophytes and other bioengineered plants could be grown as grain crops. A reforestation of tropical lands to enhance their agricultural productivity may also be possible utilizing the genetic tools provided by recombinant DNA studies.

In a nutshell, agricultural biotechnology will allow us, as the times will dictate, to do much more with a lot less. For American agriculture, it offers the opportunity to regain and retain its competitive edge in an evermore global economy and to establish again its dominance as the efficient, innovative giant. For a world where population continues to rise and fossil fuel reserves continue to fall, it may well be the next best hope we have to alleviate the growing crunch on food, energy, and chemical feedstock supplies with all its associated socioeconomic and political perils. Our global agriclimatic pattern is showing signs of the adverse impacts of the industrial effluents of the last century. Biotechnology perhaps offers some solace and remedies, born of human intelligence, to help right the wrongs our industrial excesses have caused. For us all, it offers a chance to enhance human life on earth in the next century by working in harmony with nature rather than in staunch opposition to the natural order.

All of these efforts in the area of agricultural biotechnology and genetic engineering will require a great deal of time, resources, and perserverance by agricultural and food chemists over the next decades and beyond. But for this to occur, a true cooperative partnership among industrial, agricultural, governmental, and university researchers will be crucial. We must start to raise the consciousness of the public as to the future value of the innovative biotechnology research programs our scientists are beginning today. We must educate our governmental and legislative leaders so that they better understand what will be required in the 21st century to produce substantially more with a lot less resources at our command. The funding now of biotechnological research should be viewed as a good investment in our collective future. After all, self-investment in our and our children's future is the best investment we, as a society, can make.

For 80 years, the scientists of the Agricultural and Food Chemistry Division have always responded to the challenge of applying the latest science and technology to the problems of the day. Today we already are leading research teams in a myriad of biotechnological efforts aimed at addressing future needs and concerns of the future. If we perservere in these efforts, we will be able to look back at the time of our Division's centennial with pride at how far we will have come and how much we will have accomplished for the needs of all people.

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